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TOOL INSERT

BACKGROUND OF THE INVENTION

This invention relates to tool inserts and more particularly to cutting tool inserts for use in drilling and coring holes in subterranean formations.

A commonly used cutting tool insert for drill bits is one which comprises a layer of polycrystalline diamond (PCD) bonded to a cemented carbide substrate. The layer of PCD presents a working face and a cutting edge around a portion of the periphery of the working surface.

Polycrystalline diamond, also known as a diamond abrasive compact, comprises a mass of diamond particles containing a substantial amount of direct diamond-to-diamond bonding. Polycrystalline diamond will generally have a second phase which contains a diamond catalyst/solvent such as cobalt, nickel, iron or an alloy containing one or more such metals.

In drilling operations, such a cutting tool insert is subjected to heavy loads and high temperatures at various stages of its life. In the early stages of drilling, when the sharp cutting edge of the insert contacts the subterranean formation, the cutting tool is subjected to large contact pressures. This results in the possibility of a number of fracture processes being activated such as the initiation of fatigue cracks, high energy impacts, in the normal direction, resulting in spalling of the PCD layer, and high energy impacts in the cutting direction, resulting in chipping of the PCD layer.

As the cutting edge of the insert wears, the contact pressure decreases and is generally too low to cause high energy failures. However, this pressure can still propagate cracks initiated under high contact pressures, and will eventually result in spalling-type failures.

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Spalling failures are particularly damaging in that these failures represent a mechanism for the rapid removal of wear resistant material and consequently reduce the life of the cutting tool insert. Localised spalling leads to a localised thinning of the PCD table which in turn gives rise to a grooving type of wear. This wear phenomenon redistributes the loading on the wearflat and can result in an increase in the contact pressure. As the grooving wear continues, the contact pressure will continue to increase, eventually initiating new spalling type failures from the high contact pressure areas. In a worst case scenario, this becomes a self-sustaining wear mode that will lead to the premature failure of the cutting tool due to the rapid removal of the PCD layer by a spalling mechanism.

United States 5,135,061 describes a cutting tool insert for use in rotary drill bits of the kind generally described above. The cutting element has a layer of superhard material such as PCD bonded to a cemented carbide substrate. The layer of superhard material has a front layer at the cutting face and a second layer behind the front layer. The front layer comprises a form of superhard material which is less wear-resistant than the super-hard material forming the second layer. Generally, a plurality of further layers are stacked behind the second layer, the further layers being of reducing wear-resistance as they extend away from the second layer towards the substrate.

US 6,290,008 discloses a PCD enhanced insert which includes a body portion adapted for attachment to an earth-boring bit and a top portion for contacting an earthen formation. The top portion of the insert is provided with two different compositions of polycrystalline diamond. In the primary surface of the top portion, a tougher or less wear-resistant polycrystalline diamond layer is provided, whereas a more wear-resistant polycrystalline diamond layer is provided in the remaining region of the top portion. In addition to polycrystalline diamond, polycrystalline boron nitride and other superhard materials may also be used.

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US 6,443,248 describes a cutter element for use in a drill bit, comprising a substrate and a plurality of layers thereon. The substrate comprises a grip portion and an extending portion. The layers are applied to the extending portion such that at least one of the layers is harder than at least one of the layers above it. The layers can include one or more layers of polycrystalline diamond and can include a layer in which the composition of the material changes with distance from the substrate.

SUMMARY OF THE INVENTION

According to the present invention, a tool insert comprises a working layer of ultra-hard abrasive, particularly PCD, bonded to a substrate along an interface, the working layer presenting a working surface and a periphery around the working surface which provides a cutting edge for the insert, the working layer of ultra-hard abrasive having a first region extending into the working layer from the working surface, and a second region in contact with the first region, the wear resistance of the first region being less than that of the second region, wherein the wear resistance of the first region is between 50% and 95% of that of the second region, preferably between 60% and 90%, most preferably between 70% and 89%.

Generally, the first and second regions will comprise layers, typically successive layers, extending from the working face into the working layer. The regions, or at least one of the regions, may comprise an annulus extending inwards from a periphery of the layer of ultra-hard abrasive. In some cases, the thickness of the first, thin region may be non-uniform across the diameter of the cutter; so that the interface between the first and second regions may be specifically designed for optimal behaviour.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A tool component of the invention comprises a layer of ultra-hard abrasive that has a first region which is less wear resistant than a second region thereof. Accordingly, essential to the invention is that the first region differs in material characteristics to that of the second region leading to a controlled and reduced spalling and reduced fatigue in the layer of ultra-hard abrasive. The first region will generally be relatively thin and extend to a depth of about 750 microns, preferably no more than about 500 microns, and most preferably about 50 to 250 microns, for a wear ratio of between 50% and 95%, from the working surface.

In the tool component of the invention, there is a relationship between the wear resistances of the two regions to achieve a minimising of the failure problems of prior art tool inserts described above. The first region preferably has a wear resistance of between 50% and 95%, more preferably between 60% and 90%, and most preferably between 70% and 89% of the wear resistance of the second region. An example of such a tool component, in one embodiment of the invention, is one in which the first region comprises a composite structure of two or more materials. The materials may be uniformly distributed throughout the region or randomly distributed. For example, the one material may be the same material as that of the second region and this will be combined with another material which provides that first region with a wear resistance lower than that of the second region..

This type of arrangement can also be obtained in a number of other ways. For instance, the tool component in a further embodiment of the invention can be designed such that the first and second regions are both regions of PCD and contain catalyst/solvent, the amount of catalyst/solvent in the first region being higher than that in the second region. Alternatively, the tool component in yet a further embodiment of the invention can be designed such that the first region has ultra-hard abrasive particles of a unimodal

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particle size distribution only, and the second region has ultra-hard abrasive particles which have a multimodal particle size distribution.

In both these cases, it is preferable that the average grain or particle sizes in the two regions are similar. In other words, the range of particle sizes in the second region will not differ materially from the range of particle sizes of the ultra-hard abrasive in the first region.

In a further alternative embodiment of the invention, the tool component is one in which both the first and second regions comprise ultra-hard abrasive particles of more than one particle size, the size distribution of the particles in the first region being coarser than that of the second region. In such a case, the ultra-hard abrasive in the first region is preferably made from a mass which comprises at least 25% by mass particles having an average particle size in the range 10 to 100 microns and consisting of particles having three different average particle sizes and at least 4% by mass of the particles having an average particle size of less than 10 microns. Further, the ultra-hard abrasive in the second region preferably is made from a mass of particles which has an average particle size of less than 20 microns and consists of particles having at least three different average particle sizes.

In another embodiment of the invention, the ultra-hard abrasive is PCD and the thermal stability of the PCD in the first region is less than that of the PCD in the second region. A metal or other material which has thermal expansion properties significantly different to that of PCD may be provided in the first region. Also, the first region may have a second phase which includes in it a metal such as iron or manganese which can react with the diamond under high temperature.

In a further embodiment of the invention, the ultra-hard abrasive is PCD and sinter quality of the PCD in the first region is compromised by the introduction of a material such as a sintering agent in small quantities, which is not introduced into the second region. The compromising material

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will generally not be present in quantities sufficient for the mechanical or thermal properties of the material itself to affect the properties of the first region. The role of the compromising material is to influence the diamond sintering process during synthesis. This may be achieved in one of two ways. First, the material may act as an inhibitor/poison where the agent interferes with the sintering. Second, the material may be more catalytic, for example where the presence of the material encourages sintering, but at a too rapid rate, producing a less well-sintered structure. Further examples of compromising the quality of the PCD is by treatment of the diamond particle surface or the introduction of additional carbon material into the first region.

In another embodiment of the invention, where both the first and second regions are regions of PCD containing a catalyst/solvent in a second phase, the catalyst/solvent in the first region is cobalt with another transition metal such as nickel, or the other transition metal; and the catalyst/solvent in the second region is essentially cobalt. The nickel will tend to increase the thermal stability of the PCD in the first region. However, the sintering action of the nickel is less effective than another transition metal such as cobalt. Thus, the presence of nickel in the PCD in the first region, where the other catalyst/solvent is cobalt, will have the effect of reducing the overall strength of the sintered PCD in the first region and hence rendering it less wear resistant.

The invention will now be described in more detail, by way of example only, with reference to the following non-limiting examples.

Example 1

A number of tool inserts as generally described above (A1, B1 and C1) were manufactured with respective first PCD abrasive regions or top layers each 150µm in depth from their respective working surface. The respective top layers of the tool inserts had different wear resistances relative to their respective second regions of PCD abrasive as follows:

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- i) A1 - 0.94 (94%) wear resistance ratio;
- ii) B1 - 0.91 (91%) wear resistance ratio; and
- iii) C1 - 0.88 (88%) wear resistance ratio.

These were then tested in a vertical borer test against a base PCD product X1, and the results of these tests are depicted schematically in Figure 1 of the accompanying drawings. In a vertical borer test, the wearflat area is measured as a function of the number of passes (or the total distance bored) of the cutter element boring into the workpiece, which in this case was SW granite. It will be noted that the wear behaviour improved as the wear ratio moved away from 1 at the 150 μ m depth for the respective top layers. Referring to the base PCD product X1, the "deviations" from the curve are due to instances of spalling behaviour.

In the vertical borer test, data was collected in the range of 0 – 100 passes.

Example 2

A number of tool inserts (A2, B2, C2 and D2) were manufactured with a wear ratio of the respective first regions or top layers to the respective second regions or top layers of 0.91 (91%). The respective tool inserts had different depths of the top layers from their working surfaces as follows:

- i) A2 - 750 μ m depth of first region;
- ii) B2 - 500 μ m depth of first region;
- iii) C2 - 250 μ m depth of first region; and
- iv) D2 - 150 μ m depth of first region.

These were again tested in a vertical borer test against a base PCD product X2, and the results of these tests are depicted schematically in Figure 2 of the accompanying drawings. It will be noted that at a wear ratio of 0.91, wear behaviour improved as the top layer become thinner.

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In the vertical borer test, data was collected in the range of 0 – 100 passes.

From the above Examples, the following observations can be made.

As the thickness of the top layer is increased, spalling behaviour will be reduced, but this can be at the cost of cutting efficiency. At the extreme, the wear resistance of the top layer will dominate the overall wear resistance of the cutter. Hence a thinner top layer is desirable for achieving most benefit from the more wear resistant underlying PCD. Where the wear ratio is close to 1, thinner layers will not yield the desired stress-reducing behaviours because of inadequate "rounding" of this layer. Maximum cutting efficiency will be achieved by optimising the thickness of the top layer and the wear ratio between the top layer and the underlying PCD. The top layer must be thick enough to reduce contact pressures on the cutting edge, but still thin enough that it does not negatively impact on the overall wear resistance of the cutter. The closer that the wear ratio is to 1, the less efficient this optimisation will be. In the case of lower wear ratios, the top layer will yield the required reduction in spalling behaviour, in an appropriate thickness region which still allows optimal cutter performance.

However, it is believed that this behaviour is not just a function of the relative wear ratio of the two layers and the top layer thickness, but will also be decided by the absolute strength of the material. Where this approach is applied to PCD material of lower strength, which is therefore less prone to spalling type failure, maximum benefit is unlikely to be realised.

The invention has particular application to tool inserts wherein the ultra-hard abrasive is PCD and, more particularly, to such inserts which are intended to be used as cutting inserts for drill bits in the drilling or coring of drill holes or the like in subterranean formations.